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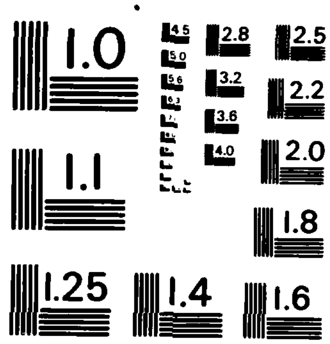
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

IMPREGNATION OF ALUMINIUM-ALLOY COMPOUNDS WITH CARBON MATERIALS

by

L. Jingxiu

FOREIGN TECHNOLOGY DIVISION

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EDITED TRANSLATION

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IMPREGNATION OF ALUMINIUM-ALLOY COMPOUNDS WITH CARBON MATERIALS

Liu Jingxiu

Sintered porous carbon substrate is mainly composed of graphite, coke and pores. It can be used as a substrate for composite materials. The composite material of carbon and aluminium-alloy can be made by immersing the compressed and sintered carbon substrate in molten aluminium alloy under a fixed pressure, which forces the molten alloy to flow into the pores of the substrate. The surface of the material under such compressed condition should have a stress of 5 $\sim$ 15 Kg/mm^2.

1. The Properties of the Composite Material

Major tests and the results of measurements of the physical, chemical and mechanical properties, the metallurgical microstructure, the fractional abrasion, the dynamic strength, as well as the X-ray studies of the internal structure and defects are summarized in the following.

(1) The Physical Properties of the Carbon Substrate

Bend Strength [Kg/cm^2]: 340 $\sim$ 400

Compressive Strength [Kg/cm^2]: 750$\sim$900

Shore Hardness: 70$\sim$75

Porosity: 20 $\sim$ 25%

Apparent Specific Gravity [g/cm^3] 1.55$\sim$1.8

Spectrum and qualitative analyses of the carbon substrate indicated the presence of small amount of copper, magnesium and iron in addition to graphite and coke. The abrasion resistance of the carbon substrate increases significantly after impregnation with metal. The best result is obtained with impregnation of aluminum alloy, which reduces the abrasion to less than 1/45 of

the original value of the substrate without impregnation. The composition of the aluminium alloy is listed in the following:

Element	Al	Si	Cu	Ni	Fe
Weight Percent	88.7	7.39	1.71	1.96	0.22

Quantitative analysis indicate that the amount of the impregnated metal alloy is 32.83% and the amount of carbon is 67.17%. The chemical composition is:

Element	Al	A	Ni	Cu	Mg	Fe	Mn	C
Weight	29.73	2.04	0.21	0.5	0.3	Trace	Trace	67.17

(2) The Physical and Mechanical Properties of the Composite Material (Table 1).

TABLE 1. The Physical and Mechanical Properties of the Composite Material

Compressive Strength	(Kg/cm^2)	4,980	Hardness	Substrate 88
Bend Strength	(Kg/cm^2)	1,864	(Shore)	White area 290.1
Ductility	($Kgcm/cm^2$)	7.6		White area with grey spots 108.4
Friction Coefficient (Coupling with chromium plated cast iron)		0.10	Linear expansion coefficient	
			50°C	9.65×10^{-6}
Apparent Specific Gravity		2.1∿2.4	300°C	9.15×10^{-6}

The compressive strength and the bend strength of the composite material of carbon substrate impregnated with aluminium alloy are about 5.5 times and 4.6 times of those of the carbon substrate material, respectively. Obviously, this is a superior material for mechanical seal applications.

Soft X-ray analysis and inspection of the internal structure of the composite material gave very sharp and clear photographs. Currently, about 42∿82% of the semifinished products can pass the quality inspection. Some products have shown serious internal defects.

2. Tests of Frictional Abrasion and Dynamic Strength

(1) Dry Friction Test

The friction test without lubrication showed that the dry friction coefficient was 0.10 and the average friction moment under enhanced dry friction condition was about 40.4 Kg.cm. The abrasion of the carbon composite material was 2.55 mm/hr. The abrasion under dry friction condition was rather high. Carbon powder flying away from the test piece and vibration of parts were observed during test. The friction surface was rather rough and some sliding traces and slight sintering were observed on the bottom surface of the test piece.

(2) Semi-dry Friction Test

Figure 1 shows the variation of the friction moment with time and the durations of oiling. The test showed that the average friction moment is 11.8 Kg/cm under the semi-dry condition. Flying carbon power was observed occasionally. However, both top and bottom friction surfaces were found smooth and shining. The tendency of bonding and welding between the test piece and the coupling parts was very small. This shows the characteristic friction resistance of the metal impregnated composite material.

(3) Impact Abrasion Test

The test showed that the frictional surface between the parts was smooth and shining and had no trace of abrasion, loose component or other damage. It shows that the material has superior abrasive resistance, self-lubrication and strength for many practical

applications. It has also good oil absorption of and can be easily lubricated by mineral oils. With small amount of lubrication oil, the friction moment is only 1/4 of that under dry friction conditions. The abrasion and vibration of the parts are greatly reduced.

(4) Dynamic Strength Test

The measured dynamic strength of the composite material is shown in Figure 2. X-ray examination of the internal structure of the composite material prepared under low compression pressure showed an uneven distribution of the impregnated metal within the carbon substrate. Figure 3 compares the dynamic strengths of the good samples with those of the unqualified samples. The results indicated that the good samples had sustained 30 min vibration and were close to or past the Japanese or American standards published in the literature. The unqualified samples broke within 7.5 minutes. The dynamic strength and the mass of various samples are not consistent. Serious tests and straight inspections should be carred out for applications which require high technical qualities.

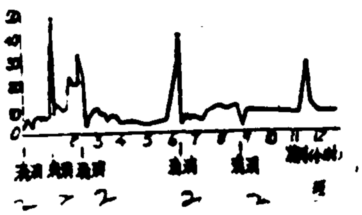

Figure 1.

Key: 1-- time (hr)
2-- oiling

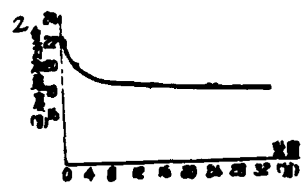

Figure 2. Characteristics of vibration acceleration vs. time.

Key: 1--time (min);
2--gravitational acceleration (g)

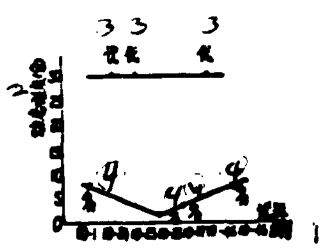

Figure 3. Comparison of the dynamic strengths of the good and the bad samples.

Key: 1--sample no.; 2--dynamic strength (min);
3--good; 4--bad.

3. Special Tests

Station and road tests of the seal pieces made from the composite material are carried out coupling with chromium plated cylinder parts. The sliding velocity between the parts is as high as 86.4 M/s. The pressure applied by the seal piece on the surface of the cylinder is also considerably high under load. The effective pressure of a general rotor machine is about 8.5 Kg/cm^2 and the thermal loading and the mechanical loading on the frictional couple are also high. Since the wall temperature of the cylinder is high (about 200∿300°C) and nonuniform (the oil film is easily destroyed) and it is difficult to apply lubrication, the surface between the seal piece and the body of the cylinder is working under semi-dry conditions. These are the major factors which cause serious abrasion.

(1) Station Test

The test was carried out on a Model 2DZ65-718 rotor machine. The result indicated that the average abrasive wear was about 0.104 mm/100 hrs along the height, 0.0343 mm/100 hrs along the length and 0.0109 mm/100 hrs along the thickness. The initial abrasion during test was rather high (0.17 mm/100 hrs) and it decreased gradually (0.58 mm/100 hrs). The maximum abrasive wear along the height after 850 hrs test on the station was 0.363 mm (abrasion limit was 2 mm).

(2) Road Test

The road test was carried out on a Model XA-620 van. The seal piece installed had passed 5000 miles road test with a maximum wear of 0.785 mm. The abrasive wear along the height was a function of the mileage as shown in Figure 4. No harmful scratch on the body of the cylinder was observed after 85000 miles. The surface was smooth and shining. The wear and distortion of the surface of the cylinder along the long and short axes were functions of the mileage as shown in Figure 5. No damage due to

drag and welding was observed during test.

The results of tests concluded that the composite material of carbon substrate impregnated with aluminium alloy compound has light weight, self-lubrication ability, good machining ability, low linear expansion coefficient, good abrasion resistance and thermal stability and is practical. It is a good material for making mechanical seals.

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